

AD-A100 449 ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND WS--ETC F/0 4/1
EXPERIMENTALLY DETERMINED RELATIONSHIP BETWEEN EXTINCTION AND L--ETC(U)
APR 81 D BRUCE, C W BRUCE, Y P YEE
ERADCOM/ASL-TR-0083

UNCLASSIFIED

NL

1 of 1
AD A
100-449



END
DATE FILMED
7-81
DTIC

ASL-TR-0083

12
AD

Reports Control Symbol

OSD-1366

EXPERIMENTALLY DETERMINED RELATIONSHIP BETWEEN
EXTINCTION AND LIQUID WATER CONTENT

APRIL 1981

By

Dorothy Bruce
Charles W. Bruce
Young Paul Yee

US Army Atmospheric Sciences Laboratory
White Sands Missile Range, New Mexico 88002

Lynn Cahenzli
Hans Burkett

New Mexico State University
Physical Science Laboratory
Las Cruces, New Mexico 88003

DTIC

2025 RELEASE UNDER E.O. 14176

JUN 22 1981

A

Approved for public release; distribution unlimited

FILE UNTIL



US Army Electronics Research and Development Command
ATMOSPHERIC SCIENCES LABORATORY

White Sands Missile Range, NM 88002

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER		2. GOVT ACCESSION NO. 3. SPONSOR/CATALOG NUMBER
ASL-TR-0083		AD-A100 449
4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
EXPERIMENTALLY DETERMINED RELATIONSHIP BETWEEN EXTINCTION AND LIQUID WATER CONTENT		R&D Technical Report
7. AUTHOR(s)		6. PERFORMING ORG. REPORT NUMBER
Dorothy Bruce Lynn Dabenzl Charles W. Bruce Dennis Burkett Young Paul Yee		
8. CONTRACT OR GRANT NUMBER(S)		
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Atmospheric Sciences Laboratory White Sands Missile Range, New Mexico 88002		11A. Task No. (IL1F1102456AD1
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE
US Army Electronics Research and Development Command Adelphi, MD 20780		April 1981
14. MONITORING/SECURITY NAME & ADDRESS (If not same as Controlling Office)		13. NUMBER OF PAGES
		29
16. DISTRIBUTION STATEMENT (If this Report)		17. SECURITY CLASS. (If different from Report)
Approved for public release; distribution unlimited.		UNCLASSIFIED
18. SUPPLEMENTARY NOTES		19. DECLASSIFICATION/DEGRADING SCHEDULE
*New Mexico State University Physical Science Laboratory Las Cruces, New Mexico 88003		
20. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
Aerosols Fog Extinction Liquid water content		
21. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
Simultaneous environmental chamber measurements have been made of $10.27\mu\text{m}$ extinction coefficients and liquid water content of droplet distributions with sizes spanning those of light to heavy fogs. The measurements yield a linear relation which is nearly independent of droplet size distribution, in agreement with recent calculated results and predictions. Liquid water content varied from 0.01 to 3.3 gm/m^3 , and droplet size distributions with single mode		

20. ABSTRACT (cont)

and bimodal differential extinction coefficient curves (extinction coefficient as a function of droplet size) were included. The spectral variation of extinction coefficient between $9.2\mu\text{m}$ and $10.8\mu\text{m}$ was also measured. The results are in good agreement with the variation calculated for typical droplet size distributions.

CONTENTS

INTRODUCTION.....	5
EXPERIMENTAL APPROACH.....	5
PRELIMINARY EXPERIMENTS.....	6
EXPERIMENTAL PROCEDURES.....	8
RESULTS.....	10
CONCLUSIONS.....	11
FIGURES.....	12

A

INTRODUCTION

An understanding of the effects of atmospheric constituents on the effectiveness of Army electro-optical systems, both actual and proposed, requires a basic understanding of relationships between propagation and meteorological or other source parameters.

This report describes simultaneous but independent measurements of the extinction coefficient due to various size distributions of water aerosols and the mass density of the water aerosol distributions. The liquid water content (LWC) measurements were made with two recently developed systems which are described in detail in Bruce et al.¹ The results are in general agreement with calculated results of Pinnick et al² based on measured fog droplet size distributions and give further verification to Chylek's³ prediction of a unique linear relation between extinction at approximately 11 μ m and LWC of fogs for all size distributions with maximum particle radii less than or approximately equal to 14 μ m.

EXPERIMENTAL APPROACH

The measurements were made in an environmental chamber having a volume of approximately 1 cubic meter. Water droplets were generated within the chamber, and minimum stirring was used to ensure uniform spatial distribution of the particles.

Figure 1 is a diagram of the optical system used in the extinction coefficient measurements. The (half power) diameter of the laser beam is approximately 1 cm in the measurement region. Early measurements made with a larger diameter (x 3) beam did not significantly improve the steadiness of the transmitted signal. The laser path through the chamber is in the vertical direction with a total length of 1.79 m. Warm dry air in the form of a thin sheet is blown across the (exterior) mirrors at the top and bottom of the chamber to prevent accumulation of water droplets on the mirror surfaces. A sample of the input beam is monitored by a reference power meter. Calculations and parametric measurements have been used to determine the attenuation necessary to prevent significant heating and evaporation of the water droplets. A mirror is rotated into the beam path to direct the beam to a spectrum analyzer during tuning of the laser.

¹C. W. Bruce, R. J. Brewer, and H. Burkett, A System for Measurement of Liquid Water Content, to be published as an ERADCOM report

²R. G. Pinnick, S. G. Jennings, P. Chylek, and J. H. Auermann, 1979, "Verification of a Linear Relation Between IR Extinction, Absorption and Liquid Water Content of Fogs," J Atmos Sci, 37:1577-1586

³P. Chylek, 1978, "Extinction and Liquid Water Content of Fogs," J Atmos Sci, 35:296-300

Sampling throats for the LWC measuring systems are located approximately in the lower center of the chamber. Sampling is at a rate of 10 to 15 liters per minute. The sampling throat of a commercial light scattering counter extends through one side of the chamber to a point close to the extinction path and the LWC sampling throats. This instrument is used to monitor the droplet size distributions and, through these, the contributions of different size particles to the extinction coefficient (differential extinction coefficient).

PRELIMINARY EXPERIMENTS

Although the measurement systems used in this study are relatively simple, several extensive preliminary investigations were conducted to provide the existence of appropriate experimental operating conditions.

The first of these investigations involved the commercial instrument used to monitor the particle size distributions--a Particle Measuring Systems (PMS) classical scattering aerosol spectrometer. This instrument is sensitive to water droplets with radii from 0.1 μ m to 16 μ m.

This instrument counts particles of different sizes by pulse height analysis of laser light (0.65 μ m) scattered by single particles into a particular solid angle. Determination of particle size is indirect because the scattering depends on particle refractive index and on the geometry of the optical system.

The instrument used in this study was checked to be sure that particles were counted in the correct size range channels. Single-size nearly transparent beads were used for channels counting particles with radii up to about 4 μ m and calibrated bead mixtures were used for channels counting particles with radii between 4 μ m and 16 μ m. Particle counting efficiency was not measured. The results from the studies with mixed bead sizes indicate that counting efficiency was relatively constant for all channels since the curves obtained with calibrated bead mixtures had the correct shapes for the size mixtures used.

Care must be exercised to limit the density of aerosol sampled by the counter since counting is based on the assumption of single scattering by individual particles and distortion of results may occur at high count rates. A variety of dilution techniques was tried in which droplet-free air was mixed with the droplet sampling stream from the chamber in the inlet throat of the PMS counter. Care was taken to minimize disturbance of the flow character. The results obtained indicate that use of these techniques extended the number density range of the instrument by a factor of about 3, but that further dilution caused definite distortion of the differential extinction curves. The differential extinction curves were used only in a relative sense; that is, the shape of the curve and the particle radius, r_p , at which peak extinction occurred were used as characteristic parameters of the chamber droplet distributions since an absolute calibration was not available to relate a measured size distribution to actual extinction coefficients and LWC.

The second of these preliminary studies was an investigation of the conditions for generation of droplet size distributions and differential extinction profiles within the ranges found in naturally occurring light to heavy fogs. Differential extinction profiles show the contribution to extinction of particles with radii in relatively small size ranges. Peak extinction for fogs normally occurs in the particle radius range of $2\mu\text{m}$ to $10\mu\text{m}$. No attempt was made to specifically tailor size distributions to be representative of any particular type of fog but rather to span typical fog droplet sizes. Maximum droplet size was approximately $16\mu\text{m}$ to permit accurate monitoring of the size distributions by the PMS spectrometer.

Commercially available "cool mist vaporizers" were used to generate droplet distributions which had monomodal differential extinction curves. The radius of peak extinction, r_p , could be varied from about $8\mu\text{m}$ to $16\mu\text{m}$ by using a variety of throttling and impaction techniques. A stable mode of operation with peak extinction at particle radii of $10\mu\text{m} \pm 1\mu\text{m}$ was finally used. Condensation droplet distributions were produced by introducing cold gaseous nitrogen into the saturated vapor of the chamber. These distributions are characterized by relatively narrow, monomodal differential extinction curves with peak extinction for droplet radii of $4\mu\text{m} \pm 1\mu\text{m}$. Both types of droplet distributions were generated with densities ranging from about 0.01 to 4.0 gm/m^3 . The shape and peak position of the differential extinction curves were not particularly sensitive to variation of the droplet number density. Typical differential extinction curves are shown in figure 2.

A study of the spatial uniformity of the droplet distributions was made by varying the location of the droplet generators and using several stirring mechanisms. Most of the mixing results from the circulation caused by the droplet generators. A small fan with specially tailored blades provides the small additional circulation (in the form of a donut within the chamber) required to obtain spatially uniform distributions.

The last of the preliminary studies involved characterization of two new sensing systems which give real-time measurements of LWC. These instruments and their characterization will be reported in detail elsewhere.¹ Only a summary will be given here.

One system involves a mass accumulation technique in which droplets are collected on a three-dimensional filter consisting of layers of flannel on a screen base. If the accumulated mass is measured and divided by the sampling time and the volume flow rate through the filter, an absolute measurement of LWC is obtained in units of mass density. The three-dimensional filter is critical to successful measurements since water droplets would clog a two-dimensional filter and lead to inaccurate sampling. Sampling times between 15 s and 4 min were used for light and heavy mass density droplet distributions and have yielded reproducible results.

¹C. W. Bruce, R. J. Brewer, and H. Burkett, A System for Measurement of Liquid Water Content, to be published as an ERADCOM report

Caution is necessary in this measurement to apply a time-dependent correction factor which results from quite rapid initial absorption of water by the dry filter fibers. This effect actually represents equilibration of the flannel to the relative humidity of the chamber. Since this effect is rapid and reproducible, the necessary correction is straightforward. Mass collection was studied to determine an adequate number of layers of flannel.

For the environmental chamber measurements, filters are preweighed in sealed containers, inserted into a sampling throat with O-ring seals, and replaced in their original container for post sampling weighing. They are then dried with a stream of ambient air for later use. A similar but real-time system is incorporated into a top loading electronic balance is also used.

The second LWC measurement system uses a differential sampling technique with phase-sensitive detection. The system has two sampling throats. One throat is vertical and unobstructed, and the flow through it contains both vapor and water droplets; the other throat contains a series of flannel filters with offset openings which create free-flow conditions through a tortuous path so that the resulting sample contains only vapor. A rotating half disc alternately selects samples from the two throats and permits them to flow through a heated woven wire grid which evaporates the droplets. The wire diameter was chosen to be much larger than the water droplets to provide a good evaporation efficiency. Evaporation of water from the grid causes cooling and a change in the grid resistance. This change results in an approximately linear change in the voltage applied across the grid by a constant current power source. The reference signal for a lock-in amplifier is obtained from the throat selected by half disc, and the synchronous voltage change across the grid is measured. The resulting signal has been shown to be proportional to the total mass density measured with the filter system in a series of measurements over a wide range of environmental chamber conditions. Single and multiple layer grids have been used, and no significant difference in results was found.

The mass collection (filter) system is used to establish the calibration of the differential system. For these measurements, the system has been used as a continuing check on the calibration; but the stability of the differential system is sufficient that such monitoring is not actually necessary.

EXPERIMENTAL PROCEDURES

Most of the extinction coefficient measurements in this study were made with the laser tuned to the 10 μ m R-16 CO₂ transition line at a wavelength of 10.27 μ m. However, several sets of spectral scans of both the 9 μ m and 10 μ m R and P bands of CO₂ were made. The laser beam power was monitored continuously, prior to the input mirror for the fog chamber (sampled by a beam splitter) and after it left the chamber. The length of the path within the chamber was 1.79 m.

Optical alignment and laser line stability were periodically checked and no problems were encountered. The power meters and the differential LWC system were stabilized, and baselines were established on the chart recorders used for data collection.

The droplet generators were then turned on, and the chamber was brought to a droplet equilibrium condition which was characterized by constant values for both transmitted laser power and differential LWC signals. After recording these values, the droplet generators were turned off, and the chamber was again allowed to reach an equilibrium with only vapor present. This procedure establishes a baseline for the measurement of changes in transmission of laser power due to droplets only.

The droplet generators were again turned on; and after equilibrium conditions were reached, a set of three filter measurements of LWC was made. PMS counter measurements were then made, and the droplet generators were turned off. After a settling time to return to vapor-only conditions, the same measurement process was repeated with a different power supplied (by use of a Variac) to the droplet generators. Variac settings between 60 and 100 percent were used to provide a variety of droplet number densities. Size distributions and the shape and position ($r_p = 10\mu\text{m} \pm 1\mu\text{m}$) of the differential extinction coefficient curves remained almost constant for all similar sets of experiments.

Different droplet size distributions were obtained by following the above procedure for establishing vapor saturation as well as equilibrium droplet conditions and then introducing cold nitrogen gas into the center of the chamber. After an initial mixing period of about 1 min, chamber conditions became essentially uniform; then both the transmitted laser power and differential LWC signals decayed (over a period of 6 to 10 min) back to those representative of ambient temperature conditions.

For some of these condensation droplet measurements, the droplet generators were turned off before the cold nitrogen was introduced. Under these conditions, the position of r_p for the differential extinction coefficient curves was at about $4\mu\text{m} \pm 1\mu\text{m}$.

When the droplet generators continued operation, the position of r_p either occurred at an intermediate position or the size distribution was bimodal with a variety of shapes and the two peak extinction positions within the range of $4\mu\text{m}$ to $10\mu\text{m}$.

Since chamber conditions varied with time for these condensation experiments, the LWC filter measurements were made only under the original equilibrium conditions to establish a calibration value for the differential LWC measurement.

The PMS counter measurements also required a special procedure. Since the counter significantly depleted the chamber's contents, size distributions were measured on alternate measurement sets for repeated conditions. There was an equilibration period when the counter was first turned on. The data for this period (about 3 s) were discarded. Then, several valid 2 s sampling sets of data were obtained.

The spectral variation of extinction was also measured. Two types of experiments were performed. In the first the specially modified laser was operated in a scanning mode. In this mode the laser can be scanned through the $9\mu\text{m}$ R and P bands and then, with a minor adjustment, through the $10\mu\text{m}$ R and P

bands. A complete scan of these bands takes approximately 1 h. These data were somewhat noisy so another experimental procedure was also used.

The second set of spectral data was obtained by manually tuning the laser to four separate spectral lines in each of the four bands and measuring the extinction. The lines used (10, 18, 24, and 30) were chosen to be fairly evenly distributed across each band. Data were taken by using the same general procedures as those used in the other experiments, with droplet generation conditions typical of those which produced differential extinction peaks at approximately 10 μ m.

Environmental chamber conditions for these spectral scans were the same as the conditions for equilibrium droplet generation for the detailed 10, 18, 24, and 30 experiments. No condensation droplet distributions were included since these were unstable, and the experiments would be time-consuming and difficult to interpret.

RESULTS

The measured relationship between the extinction coefficient at 10 μ m and the LWC of environmental chamber droplet distributions is shown in figures 3a through 3c.

Each type of size distribution clearly shows a linear relation between the measured quantities. The ratio between them shows some variation as a function of the droplet distribution generation mechanism: the slope for mechanically generated distributions (figure 3a) is 152 $\text{km}^{-1}/(\text{gm}/\text{m}^3)$, for condensation droplet distributions (figure 3b) 158 $\text{km}^{-1}/(\text{gm}/\text{m}^3)$, and for the combination of distributions (figure 3c) 156 $\text{km}^{-1}/(\text{gm}/\text{m}^3)$, although it could presumably vary anywhere between the other two values.

However, the data for all of the distributions may be combined to yield a linear relation with a slope of 154 $\text{km}^{-1}/(\text{gm}/\text{m}^3)$ with a combined experimental error of 12 $\text{km}^{-1}/(\text{gm}/\text{m}^3)$ or 8 percent.

The PMS counter measurements of the size distributions were used in a Mie scattering program calculation of LWC and extinction coefficient (using a previously measured value for the complex index of refraction for water at this wavelength by Hale et al.¹). The ratio of the calculated quantities of $156 \pm 17 \text{ km}^{-1}/(\text{gm}/\text{m}^3)$ agrees within the experimental error with that of the measured slopes. This agreement was true even though the calculated values of the extinction coefficients and LWC were close to the measured values for one counter used but were very different for another similar unit.

Figure 4 is a comparison of the average measured extinction for each spectral band with the values calculated from measured droplet size distributions.

¹G. M. Hale and M. R. Querry, 1973, "Optical Constants of Water in the 200-nm to 20 μ m Wavelength Region," Appl Opt, 12:555-563

Averages of both sets of measurements are shown, with the RMS data spread shown for the data set obtained by manually tuning the laser. The data taken with automatic tuning have a larger spread. Some of the lines measured in this mode of operation were not included in the band averages. These averages were chosen by plotting measured power for all lines in a band and discarding points which did not fall close to a Boltzmann-like profile. Approximately six lines (38 percent of total) were included in each average. The measured averages are plotted at the median wavelength for the lines used.

Two sets of calculated extinction coefficients are shown. These sets give the calculated spectral dependence of the extinction coefficient for typical droplet distributions with primarily large and small droplet sizes. The peak differential extinction coefficients occurred at approximately 8.8 μm and 4.2 μm for the droplet distributions used.

All data have been scaled to agree at 10.3 μm since the other measurements reported here show that the extinction coefficient is independent of droplet size distribution and linearly dependent on LWC at that wavelength.

CONCLUSIONS

Measurements have been made of the extinction coefficient at 10.27 μm and, independently, of the LWC of a large number of environmental chamber droplet size distributions with radii spanning those of a variety of fogs. A linear relation has been found which is approximately independent of the size distribution. The measured ratio of extinction coefficient to LWC is 159 $\text{km}^{-1}/(\text{gm}/\text{m}^3)$.

These results are in good agreement with the linear relation predicted by Chylek¹ and calculated by Pinnick et al² at 11 μm based on size distribution measurements of fogs and hazes.

Measurements of the spectral dependence of the extinction coefficient (between 9.2 μm and 10.8 μm) have been made and are in good agreement with the dependence calculated for two typical droplet size distributions.

Systems for the measurement of LWC under field conditions have been developed from those used in this study and were used in the Meppen 80 field tests.

The results obtained from the experiments reported here suggest that it would be possible to use measurements of LWC to predict performance in fogs and hazes of EO systems operating in the 10 μm atmospheric window.

¹P. Chylek, 1978, "Extinction and Liquid Water Content of Fogs," J Atmos Sci., 35:296-300

²R. G. Pinnick, S. G. Jennings, P. Chylek, and J. H. Auermann, 1979, "Verification of a Linear Relation Between IR Extinction, Absorption and Liquid Water Content of Fogs," J Atmos Sci., 37:1577-1586

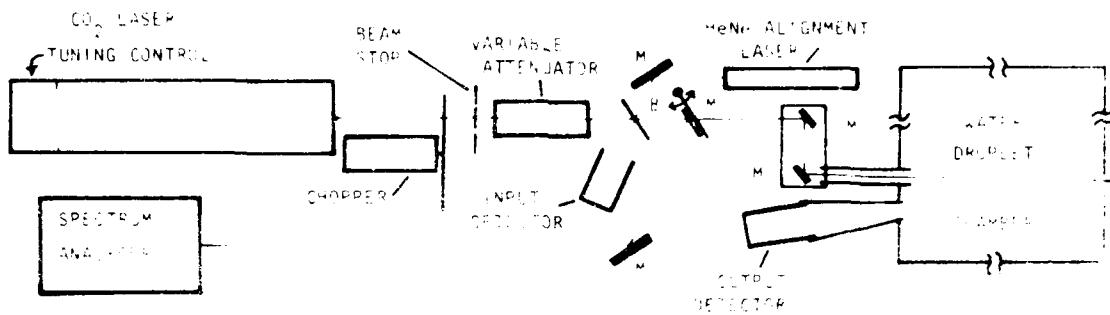


Figure 1. Optical system. M represents mirrors. B represents beam splitter. One mirror is rotatable to permit laser line identification. The CO₂ laser incorporates automatic line scanning and stabilization. An optical beam chopper is retained so that an aerosol spectrophotometer measures absorption coefficient and alternate detectors for other lasers may be used. An adjustable aperture for the CO₂ laser beam, window flush for the input and output mirrors, liquid water content measurement systems, and particle counter are omitted in this diagram.

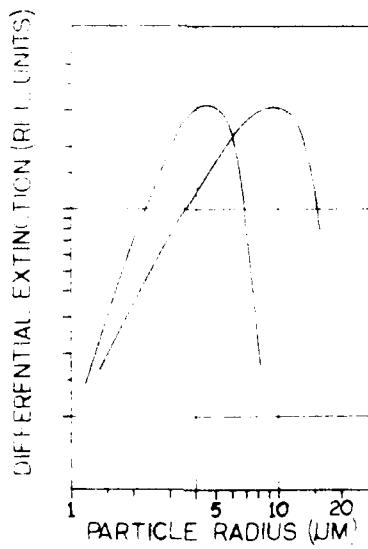
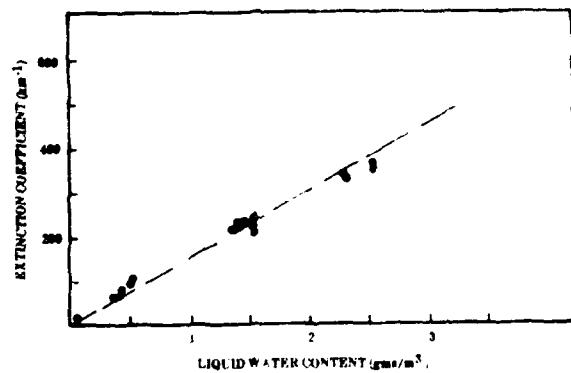
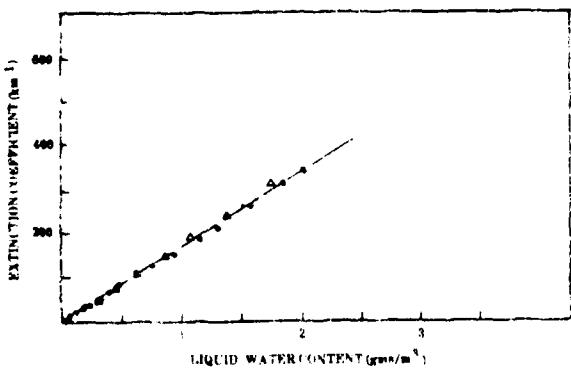


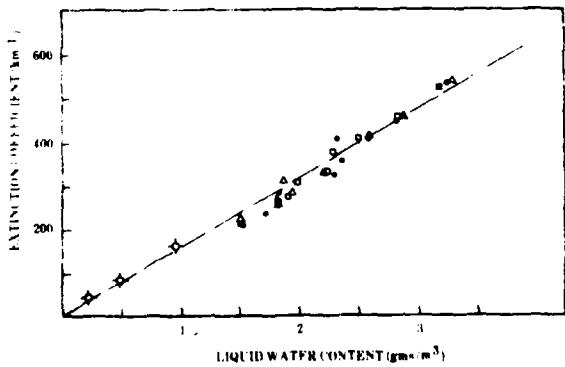
Figure 2. Typical differential extinction curves for condensation droplet (left peak) and mechanically generated (right peak) size distributions.



(a) Mechanically generated droplet size distributions.



(b) Condensation droplet size distributions.



(c) Droplet distributions generated by combinations of the mechanical and condensation techniques.

Figure 3. Extinction coefficients as functions of liquid water content for mechanically generated, condensation, and combination droplet size distributions.

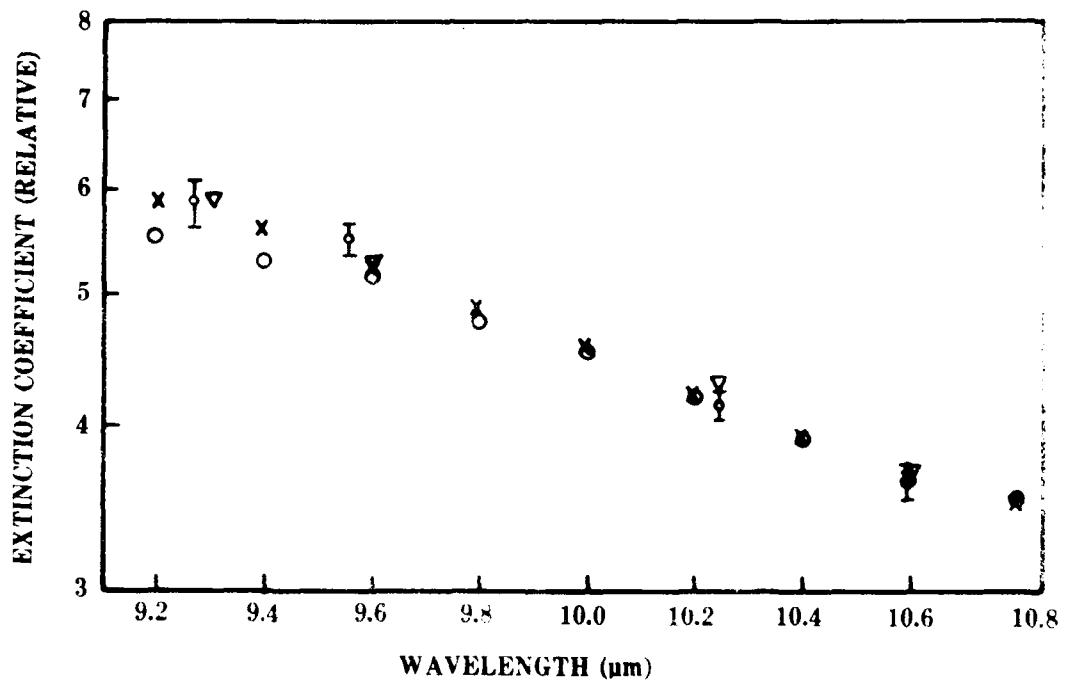


Figure 4. Measured and calculated extinction coefficients. The measured data points are averages for the spectral band plotted at the median wavelength for the lines used. The RMS data spread is indicated for the manually tuned measurement set (Φ). The data spread for the automatically scanned measurements (∇) is of the same order of magnitude. The calculations are for typical droplet size distributions with peak differential extinction at droplet radii r_p of approximately $8.8\mu\text{m}$ (\circ) and $4.5\mu\text{m}$ (\times).

ATMOSPHERIC SCIENCES RESEARCH REPORTS

1. Lindberg, J. D., "An Improvement to a Method for Measuring the Absorption Coefficient of Atmospheric Dust and other Strongly Absorbing Powders," ECOM-5565, July 1975.
2. Avara, Elton P., "Mesoscale Wind Shears Derived from Thermal Winds," ECOM-5566, July 1975.
3. Gomez, Richard B., and Joseph H. Pierluissi, "Incomplete Gamma Function Approximation for King's Strong-Line Transmittance Model," ECOM-5567, July 1975.
4. Blanco, A. J., and B. F. Engebos, "Ballistic Wind Weighting Functions for Tank Projectiles," ECOM-5568, August 1975.
5. Taylor, Fredrick J., Jack Smith, and Thomas H. Pries, "Crosswind Measurements through Pattern Recognition Techniques," ECOM-5569, July 1975.
6. Walters, D. L., "Crosswind Weighting Functions for Direct-Fire Projectiles," ECOM-5570, August 1975.
7. Duncan, Louis D., "An Improved Algorithm for the Iterated Minimal Information Solution for Remote Sounding of Temperature," ECOM-5571, August 1975.
8. Robbiani, Raymond L., "Tactical Field Demonstration of Mobile Weather Radar Set AN/TPS-41 at Fort Rucker, Alabama," ECOM-5572, August 1975.
9. Miers, R., G. Blackman, D. Langer, and N. Lorimier, "Analysis of SMS/GOES Film Data," ECOM-5573, September 1975.
10. Manquero, Carlos, Louis Duncan, and Rufus Bruce, "An Indication from Satellite Measurements of Atmospheric CO₂ Variability," ECOM-5574, September 1975.
11. Petracca, Carmine, and James D. Lindberg, "Installation and Operation of an Atmospheric Particulate Collector," ECOM-5575, September 1975.
12. Avara, Elton P., and George Alexander, "Empirical Investigation of Three Iterative Methods for Inverting the Radiative Transfer Equation," ECOM-5576, October 1975.
13. Alexander, George D., "A Digital Data Acquisition Interface for the SMS Direct Readout Ground Station - Concept and Preliminary Design," ECOM-5577, October 1975.
14. Cantor, Israel, "Enhancement of Point Source Thermal Radiation Under Clouds in a Nonattenuating Medium," ECOM-5578, October 1975.

15. Norton, Colburn, and Glenn Hoidal, "The Diurnal Variation of Mixing Height by Month over White Sands Missile Range, NM," ECOM-5579, November 1975.
16. Avara, Elton P., "On the Spectrum Analysis of Binary Data," ECOM-5580, November 1975.
17. Taylor, Fredrick J., Thomas H. Pries, and Chao-Huan Huang, "Optimal Wind Velocity Estimation," ECOM-5581, December 1975.
18. Avara, Elton P., "Some Effects of Autocorrelated and Cross-Correlated Noise on the Analysis of Variance," ECOM-5582, December 1975.
19. Gillespie, Patti S., R. L. Armstrong, and Kenneth O. White, "The Spectral Characteristics and Atmospheric CO₂ Absorption of the Ho⁺³:YLF Laser at 2.05-m," ECOM-5583, December 1975.
20. Novlan, David J., "An Empirical Method of Forecasting Thunderstorms for the White Sands Missile Range," ECOM-5584, February 1976.
21. Avara, Elton P., "Randomization Effects in Hypothesis Testing with Auto-correlated Noise," ECOM-5585, February 1976.
22. Watkins, Wendell R., "Improvements in Long Path Absorption Cell Measurement," ECOM-5586, March 1976.
23. Thomas, Joe, George D. Alexander, and Marvin Dubbin, "SATTEL - An Army Dedicated Meteorological Telemetry System," ECOM-5587, March 1976.
24. Kennedy, Bruce W., and Delbert Bynum, "Army User Test Program for the RDT&E-XM-75 Meteorological Rocket," ECOM-5588, April 1976.
25. Barnett, Kenneth M., "A Description of the Artillery Meteorological Comparisons at White Sands Missile Range, October 1974 - December 1974 ('PASS' - Prototype Artillery [Meteorological] Subsystem)," ECOM-5589, April 1976.
26. Miller, Walter B., "Preliminary Analysis of Fall-of-Shot From Project 'PASS'," ECOM-5590, April 1976.
27. Avara, Elton P., "Error Analysis of Minimum Information and Smith's Direct Methods for Inverting the Radiative Transfer Equation," ECOM-5591, April 1976.
28. Yee, Young P., James D. Horn, and George Alexander, "Synoptic Thermal Wind Calculations from Radiosonde Observations Over the Southwestern United States," ECOM-5592, May 1976.
29. Duncan, Louis D., and Mary Ann Seagraves, "Applications of Empirical Corrections to NOAA-4 VTPR Observations," ECOM-5593, May 1976.

30. Miers, Bruce T., and Steve Weaver, "Applications of Meteorological Satellite Data to Weather Sensitive Army Operations," ECOM-5594, May 1976.
31. Sharenow, Moses, "Redesign and Improvement of Balloon ML-566," ECOM-5595, June 1976.
32. Hansen, Frank V., "The Depth of the Surface Boundary Layer," ECOM-5596, June 1976.
33. Pinnick, R. G., and E. R. Stenmark, "Response Calculations for a Commercial Light-Scattering Aerosol Counter," ECOM-5597, July 1976.
34. Mason, J., and G. B. Hoidal, "Visibility as an Estimator of Infrared Transmittance," ECOM-5598, July 1976.
35. Bruce, Rufus E., Louis D. Duncan, and Joseph H. Pierluissi, "Experimental Study of the Relationship Between Radiosonde Temperatures and Radiometric-Area Temperatures," ECOM-5599, August 1976.
36. Duncan, Louis D., "Stratospheric Wind Shear Computed from Satellite Thermal Sounder Measurements," ECOM-5800, September 1976.
37. Taylor, F., P. Mohan, P. Joseph, and T. Pries, "An All Digital Automated Wind Measurement System," ECOM-5801, September 1976.
38. Bruce, Charles, "Development of Spectrophones for CW and Pulsed Radiation Sources," ECOM-5802, September 1976.
39. Duncan, Louis D., and Mary Ann Seagraves, "Another Method for Estimating Clear Column Radiiances," ECOM-5803, October 1976.
40. Blanco, Abel J., and Larry E. Taylor, "Artillery Meteorological Analysis of Project Pass," ECOM-5804, October 1976.
41. Miller, Walter, and Bernard Engebos, "A Mathematical Structure for Refinement of Sound Ranging Estimates," ECOM-5805, November 1976.
42. Gillespie, James B., and James D. Lindberg, "A Method to Obtain Diffuse Reflectance Measurements from 1.0 and 3.0 μ m Using a Cary 17I Spectrophotometer," ECOM-5806, November 1976.
43. Rubio, Roberto, and Robert O. Olsen, "A Study of the Effects of Temperature Variations on Radio Wave Absorption," ECOM-5807, November 1976.
44. Ballard, Harold N., "Temperature Measurements in the Stratosphere from Balloon-Borne Instrument Platforms, 1968-1975," ECOM-5808, December 1976.

45. Monahan, H. H., "An Approach to the Short-Range Prediction of Early Morning Radiation Fog," ECOM-5809, January 1977.
46. Engebos, Bernard Francis, "Introduction to Multiple State Multiple Action Decision Theory and Its Relation to Mixing Structures," ECOM-5810, January 1977.
47. Low, Richard D. H., "Effects of Cloud Particles on Remote Sensing from Space in the 10-Micrometer Infrared Region," ECOM-5811, January 1977.
48. Bonner, Robert S., and R. Newton, "Application of the AN/GVS-5 Laser Rangefinder to Cloud Base Height Measurements," ECOM-5812, February 1977.
49. Rubio, Roberto, "Lidar Detection of Subvisible Reentry Vehicle Erosive Atmospheric Material," ECOM-5813, March 1977.
50. Low, Richard D. H., and J. D. Horn, "Mesoscale Determination of Cloud-Top Height: Problems and Solutions," ECOM-5814, March 1977.
51. Duncan, Louis D., and Mary Ann Leagraves, "Evaluation of the NOAA-4 VTPR Thermal Winds for Nuclear Fallout Predictions," ECOM-5815, March 1977.
52. Randhawa, Jagir S., M. Izquierdo, Carlos McDonald, and Zvi Salpeter, "Stratospheric Ozone Density as Measured by a Chemiluminescent Sensor During the Stratos- VI-A Flight," ECOM-5816, April 1977.
53. Rubio, Roberto, and Mike Izquierdo, "Measurements of Net Atmospheric Irradiance in the 0.7- to 2.8-Micrometer Infrared Region," ECOM-5817, May 1977.
54. Ballard, Harold N., Jose M. Serna, and Frank P. Hudson, Consultant for Chemical Kinetics, "Calculation of Selected Atmospheric Composition Parameters for the Mid-Latitude, September Stratosphere," ECOM-5818, May 1977.
55. Mitchell, J. D., R. S. Sagar, and R. O. Olsen, "Positive Ions in the Middle Atmosphere During Sunrise Conditions," ECOM-5819, May 1977.
56. White, Kenneth O., Wendell R. Watkins, Stuart A. Schleusener, and Ronald L. Johnson, "Solid-State Laser Wavelength Identification Using a Reference Absorber," ECOM-5820, June 1977.
57. Watkins, Wendell R., and Richard G. Dixon, "Automation of Long-Path Absorption Cell Measurements," ECOM-5821, June 1977.
58. Taylor, S. E., J. M. Davis, and J. B. Mason, "Analysis of Observed Soil Skin Moisture Effects on Reflectance," ECOM-5822, June 1977.

59. Duncan, Louis D., and Mary Ann Seagraves, "Fallout Predictions Computed from Satellite Derived Winds," ECOM-5823, June 1977.
60. Snider, D. E., D. G. Murcay, F. H. Murcay, and W. J. Williams, "Investigation of High-Altitude Enhanced Infrared Backround Emissions," (U), SECRET, ECOM-5824, June 1977.
61. Dubbin, Marvin H., and Dennis Hall, "Synchronous Meteorological Satellite Direct Readout Ground System Digital Video Electronics," ECOM-5825, June 1977.
62. Miller, W., and B. Engehos, "A Preliminary Analysis of Two Sound Ranging Algorithms," ECOM-5826, July 1977.
63. Kennedy, Bruce W., and James K. Luers, "Ballistic Sphere Techniques for Measuring Atmospheric Parameters," ECOM-5827, July 1977.
64. Duncan, Louis D., "Zenith Angle Variation of Satellite Thermal Sounder Measurements," ECOM-5828, August 1977.
65. Hansen, Frank V., "The Critical Richardson Number," ECOM-5829, September 1977.
66. Ballard, Harold N., and Frank P. Hudson (Compilers), "Stratospheric Composition Balloon-Borne Experiment," ECOM-5830, October 1977.
67. Barr, William C., and Arnold C. Peterson, "Wind Measuring Accuracy Test of Meteorological Systems," ECOM-5831, November 1977.
68. Ethridge, G. A., and F. V. Hansen, "Atmospheric Diffusion: Similarity Theory and Empirical Derivations for Use in Boundary Layer Diffusion Problems," ECOM-5832, November 1977.
69. Low, Richard D. H., "The Internal Cloud Radiation Field and a Technique for Determining Cloud Blackness," ECOM-5833, December 1977.
70. Watkins, Wendell R., Kenneth O. White, Charles W. Bruce, Donald L. Walters, and James D. Lindberg, "Measurements Required for Prediction of High Energy Laser Transmission," ECOM-5834, December 1977.
71. Rubio, Robert, "Investigation of Abrupt Decreases in Atmospherically Backscattered Laser Energy," ECOM-5835, December 1977.
72. Monahan, H. H., and R. M. Cionco, "An Interpretative Review of Existing Capabilities for Measuring and Forecasting Selected Weather Variables (Emphasizing Remote Means)," ASL-TR-0001, January 1978.
73. Heaps, Melvin G., "The 1979 Solar Eclipse and Validation of D-Region Models," ASL-TR-0002, March 1978.

74. Jennings, S. G., and J. R. Grimespie, "M.I.E. Theory Sensitivity Studies - The Effects of Aerosol Complex Refractive Index and Size Distribution Variations on Extinction and Absorption Coefficients, Part II. Analysis of the Computational Results," ASL-TR-0003, March 1978.
75. White, Kenneth D., et al, "Water Vapor Continuum Absorption in the 3.5 μ m to 4.0 μ m Region," ASL-TR-0004, March 1978.
76. Olsen, Robert C., and Bruce F. Kennedy, "ARRES Pretest Atmospheric Measurements," ASL-TR-0005, April 1978.
77. Ballard, Harold S., Jose M. Cane, and Frank D. Hudson, "Calculation of Atmospheric Composition in the High Latitude Stratosphere," ASL-TR-0006, May 1978.
78. Watkins, Wendell R., et al, "Water Vapor Absorption Coefficients at HF Laser Wavelengths," ASL-TR-0007, May 1978.
79. Hansen, Frank V., "The Brewer Day Prediction of nocturnal Inversions," ASL-TR-0008, May 1978.
80. Samuel, Christine, Charles D. J., and Ralph Brewer, "Spectrophone Analysis of Gas Samples Collected at Field Station," ASL-TR-0009, June 1978.
81. Pinnick, R. G., et al., "Vertical Structure in Atmospheric Fog and Haze and its Effects on Extinction," ASL-TR-0010, July 1978.
82. Low, Richard D. H., Louis D. Duncan, and Richard R. Gomez, "The Microphysical Basis of Cloud Optical Characterization," ASL-TR-0011, August 1978.
83. Heaps, Melvin C., "The Effect of a Solar Proton Event on the Minor Neutral Constituents of the Summer Polar Mesosphere," ASL-TR-0012, August 1978.
84. Mason, James R., "Light Attenuation in Falling Snow," ASL-TR-0013, August 1978.
85. Blanco, Abel J., "Long-Range Artillery Sound Ranging: 'PASS' Meteorological Application," ASL-TR-0014, September 1978.
86. Heaps, M. G., and F. E. Niles, "Modeling of Ion Chemistry of the D-Region: A Case Study Based Upon the 1966 Total Solar Eclipse," ASL-TR-0015, September 1978.
87. Jennings, S. G., and R. G. Pinnick, "Effects of Particulate Complex Refractive Index and Particle Size Distribution Variations on Atmospheric Extinction and Absorption for Visible Through Middle-Infrared Wavelengths," ASL-TR-0016, September 1978.

88. Watkins, Wendell R., Kenneth O. White, Lanny R. Bower, and Brian Z. Sojka, "Pressure Dependence of the Water Vapor Continuum Absorption in the 3.5- to 4.0-Micrometer Region," ASL-TR-0017, September 1978.
89. Miller, W. B., and B. F. Engebos, "Behavior of Four Sound Ranging Techniques in an Idealized Physical Environment," ASL-TR-0018, September 1978.
90. Gomez, Richard G., "Effectiveness Studies of the CBU-88/B Bomb, Cluster, Smoke Weapon," (U), CONFIDENTIAL ASL-TR-0019, September 1978.
91. Miller, August, Richard C. Shirkey, and Mary Ann Seagraves, "Calculation of Thermal Emission from Aerosols Using the Doubling Technique," ASL-TR-0020, November 1978.
92. Lindberg, James D., et al, "Measured Effects of Battlefield Dust and Smoke on Visible, Infrared, and Millimeter Wavelengths Propagation: A Preliminary Report on Dusty Infrared Test-I (DIRT-I)," ASL-TR-0021, January 1979.
93. Kennedy, Bruce W., Arthur Kinghorn, and B. R. Hixon, "Engineering Flight Tests of Range Meteorological Sounding System Radiosonde," ASL-TR-0022, February 1979.
94. Rubio, Roberto, and Don Hoock, "Microwave Effective Earth Radius Factor Variability at Wiesbaden and Balboa," ASL-TR-0023, February 1979.
95. Low, Richard D. H., "A Theoretical Investigation of Cloud/Fog Optical Properties and Their Spectral Correlations," ASL-TR-0024, February 1979.
96. Pinnick, R. G., and H. J. Auermann, "Response Characteristics of Knollenberg Light-Scattering Aerosol Counters," ASL-TR-0025, February 1979.
97. Heaps, Melvin G., Robert O. Olsen, and Warren W. Berning, "Solar Eclipse 1979, Atmospheric Sciences Laboratory Program Overview," ASL-TR-0026, February 1979.
98. Blanco, Abel J., "Long-Range Artillery Sound Ranging: 'PASS' GR-8 Sound Ranging Data," ASL-TR-0027, March 1979.
99. Kennedy, Bruce W., and Jose M. Serna, "Meteorological Rocket Network System Reliability," ASL-TR-0028, March 1979.
100. Swingle, Donald M., "Effects of Arrival Time Errors in Weighted Range Equation Solutions for Linear Base Sound Ranging," ASL-TR-0029, April 1979.
101. Umstead, Robert K., Ricardo Pena, and Frank V. Hansen, "KWIK: An Algorithm for Calculating Munition Expenditures for Smoke Screening/Obscuration in Tactical Situations," ASL-TR-0030, April 1979.

102. D'Arcy, Edward M., "Accuracy Validation of the Solidified Nike Hercules Radar," ASL-TR-0031, May 1979.
103. Rodriguez, Ruben, "Evaluation of the Passive Remote Crosswind Sensor," ASL-TR-0032, May 1979.
104. Barber, T. L., and R. Rodriguez, "Infrared Remote Lidar Measurement of Near-Surface Wind Velocity," ASL-TR-0033, June 1979.
105. Low, Richard E. H., Luterbacher, Duncan, and M. M. Lutz, "A Study of the Physical Properties of the Dust Cloud from the 1976 White Sands Test," ASL-TR-0036, June 1979.
106. Rodriguez, Ruben, and William J. Lenz, "Evaluation of the Saturated Airflow Test Facility," ASL-TR-0037, July 1979.
107. Ohmstede, William G., "The Dynamics of Material Transport," ASL-TR-0038, July 1979.
108. Pinnick, R. J., et al., "A Method of Determining the Water Content of Dust," "Relationships Between the Extinction Absorption Coefficient and the Water Content of Dust," ASL-TR-0039, August 1979.
109. Rodriguez, Ruben, and R. Rodriguez, "Characterization Evaluation of the Saturated Airflow Test Facility," ASL-TR-0040, August 1979.
110. Mies, Robert L., "A Test of the Wind Tunnel Dust Collector," ASL-TR-0041, September 1979.
111. Dickson, Paul, and Lutz, M. Lutz, "Helicopter Remote Sensing of Dust Cloud Concentration," ASL-TR-0042, September 1979.
112. Heaps, Melvin L., and Joseph K. Heimerl, "Validation of the Dairchem Particle Counter Under Dusty Conditions," ASL-TR-0043, September 1979.
113. Bonner, Robert S., and William J. Lenz, "The Visioceilometer: A Portable Counter for Visibility Indicator," ASL-TR-0042, October 1979.
114. Corn, Stephen L., "The Role of Atmospheric Sulfates in Battlefield Obscurations," ASL-TR-0043, October 1979.
115. Fawbush, S. L., et al, "Characterization of Atmospheric Conditions at the High Energy Laser System Test Facility (HELSTF), White Sands Missile Range, New Mexico, Part I, 24 March to 8 April 1977," ASL-TR-0044, November 1979.
116. Barber, Ted L., "Short-Time Mass Variation in Natural Atmospheric Dust," ASL-TR-0045, November 1979.

117. Low, Richard D. H., "Fog Evolution in the Visible and Infrared Spectral Regions and its Meaning in Optical Modeling," ASL-TR-0046, December 1979.
118. Duncan, Louis D., et al, "The Electro-Optical Systems Atmospheric Effects Library, Volume 1: Technical Documentation," ASL-TR-0047, December 1979.
119. Shirkey, R. C., et al, "Interim E-0 SAEL, Volume II, Users Manual," ASL-TR-0048, December 1979.
120. Kobayashi, H. K., "Atmospheric Effects on Millimeter Radio Waves," ASL-TR-0049, January 1980.
121. Seagraves, Mary Ann, and Louis D. Duncan, "An Analysis of Transmittances Measured Through Battlefield Dust Clouds," ASL-TR-0050, February 1980.
122. Dickson, David H., and Jon S. Ottesen, "Helicopter Remote Wind Sensor Flight Test," ASL-TR-0051, February 1980.
123. Pinnick, R. G., and S. G. Jennings, "Relationships Between Radiative Properties and Mass Content of Phosphoric Acid, HC, Petroleum Oil, and Sulfuric Acid Military Smokes," ASL-TR-0052, April 1980.
124. Hinds, B. D., and J. B. Gillespie, "Optical Characterization of Atmospheric Particulates on San Nicolas Island, California," ASL-TR-0053, April 1980.
125. Miers, Bruce T., "Precipitation Estimation for Military Hydrology," ASL-TR-0054, April 1980.
126. Stenmark, Ernest B., "Objective Quality Control of Artillery Computer Meteorological Messages," ASL-TR-0055, April 1980.
127. Duncan, Louis D., and Richard D. H. Low, "Bimodal Size Distribution Models for Fogs at Meppen, Germany," ASL-TR-0056, April 1980.
128. Olsen, Robert U., and Jagir S. Randhawa, "The Influence of Atmospheric Dynamics on Ozone and Temperature Structure," ASL-TR-0057, May 1980.
129. Kennedy, Bruce W., et al, "Dusty Infrared Test-II (DIRT-II) Program," ASL-TR-0058, May 1980.
130. Heaps, Melvin G., Robert U. Olsen, Warren Berning, John Cross, and Arthur Giuseppe, "1979 Solar Eclipse, Part I - Atmospheric Sciences Laboratory Field Program Summary," ASL-TR-0059, May 1980.
131. Miller, Walter B., "User's Guide for Passive Target Acquisition Program Two (PTAP-2)," ASL-TR-0060, June 1980.

132. Holt, E. H., editor, "Environmental Data Requirements for Battlefield Obscuration Analysis," ASL-TR-0061, June 1980.
133. Shirkey, Michael J., Louis Miller, George A. Goedert, and David A., "Single Scattering Code (USA): Theory, Applications, Documentation and Listing," ASL-TR-0062, July 1980.
134. Sojka, Brian Z., and Kenneth E. White, "Evaluation of Six Acoustic Photoacoustic Absorption Chambers for Near-Millimeter Wavelength Propagation Measurements," ASL-TR-0063, August 1980.
135. Bruce, Charles W., Young R. Yee, and S. G. Jennings, "Direct Measurements of the Coefficients of Aerosol Absorption and Extinction Coefficients," ASL-TR-0064, August 1980.
136. Yee, Young Rui, Charles W. Bruce, and Ralph D. Brewster, "Aerosol Extinction Coefficient Determination at 1.06 μ m Using Laser Light Spectrometers," ASL-TR-0065, June 1980.
137. Lindberg, James D., Peter J. Loveland, Melvin Heaps, James D. Heaps, and Andrew C. M. Smith, "Atmospheric and Meteorological Characterization Measurements During West German Meteorological Conditions in Support of Grafenwoehr Tests," ASL-TR-0066, January 1980.
138. Vechione, W. J., "Evaluation of the Environmental Instruments, Incorporated Series 10 Dual Component Wind Set," ASL-TR-0067, September 1980.
139. Bruce, C. W., Y. R. Yee, S. G. Hinds, R. G. Pinnick, R. L. Brewster, and J. Minigres, "Initial Wind Measurements of Atmospheric Ionization at 960 cm⁻¹ Wavelet," ASL-TR-0068, October 1980.
140. Heaps, M. G., R. U. Olsen, K. D. Baker, D. A. Burt, L. C. Howlett, L. L. Jensen, L. F. Pound, and G. D. Alfred, "1979 Solar Eclipse: Part II. Initial Results for Ionization Sources, Electron Density, and Minor Neutral Constituents," ASL-TR-0069, October 1980.
141. Low, Richard D. H., "One-Dimensional Cloud Microphysical Models for Central Slope and Valley Optical Properties," ASL-TR-0070, October 1980.
142. Duncan, Louis D., James D. Lindberg, and Radon B. Loveland, "An Empirical Model of the Vertical Structure of German Fogs," ASL-TR-0071, November 1980.
143. Duncan, Louis D., 1981, "EUSAEL 80, Volume I, Technical Documentation," ASL-TR-0072, January 1981.
144. Shirkey, R. C., and S. G. O'Brien, "EOSALL 80, Volume II, Users Manual," ASL-TR-0073, January 1981.
145. Bruce, C. W., "Characterization of Aerosol Nonlinear Effects on a High-Power CO₂ Laser Beam," ASL-TR-0074, February 1981.

146. Duncan, Louis D., and James D. Lindberg, "Air Mass Considerations in Fog Optical Modeling," ASL-TR-0076, February 1981.
147. Kunkel, Kenneth E., "Evaluation of a Tethered Kite Anemometer," ASL-TR-0076, February 1981.
148. Kunkel, K. E., et al, "Characterization of Atmospheric Conditions at the High Energy Laser System Test Facility (HELST) White Sands Missile Range, New Mexico, August 1977 to October 1978, Part II, Critical Turbulence, Wind, Water Vapor Pressure, Temperature," ASL-TR-0077, February 1981.
149. Miers, Bruce T., "Weather Scenarios for Central Wyoming," ASL-TR-0078, February 1981.
150. Sojarn, James L., "Sensitivity Analysis of a Mesoscale Moisture Model," ASL-TR-0079, March 1981.
151. Brewer, R. J., C. W. Bruce, and J. L. Peter, "Cetoacoustic Spectroscopy of C_2H_6 at the $9\mu m$ and $10\mu m$ $CH_2^{12}C^{13}$ Laser Wavelengths," ASL-TR-0080, March 1981.
152. Swingle, Donald M., "Reducible Errors in the Artillery Sound Ranging Solution, Part I: The Curvature Correction" (U), SECRET, ASL-TR-0081, April 1981.
153. Miller, Walter B., "The Existence and Implications of a Fundamental System of Linear Equations in Sound Ranging" (U), SECRET, ASL-TR-0082, April 1981.
154. Bruce, Dorothy, Charles W. Bruce, and Young Paul Yee, "Experimentally Determined Relationship between Extinction and Liquid Water Content," ASL-TR-0083, April 1981.

DISTRIBUTION LIST

Commander
US Army Aviation Center
ATTN: ATZQ-D-MA
Fort Rucker, AL 36362

Chief, Atmospheric Sciences Div
Code ES-81
NASA
Marshall Space Flight Center, AL 35812

Commander
US Army Missile Command
ATTN: DRDMI-RRA (P.O. M. Essenschen)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-CG (B. W. Fowler)
Redstone Arsenal, AL 35809

Commander
US Army Missile R&D Command
ATTN: DRDMI-TEM (R. Faraway)
Redstone Arsenal, AL 35809

Redstone Scientific Information Center
ATTN: DRSMI-RRBD (Documents)
US Army Missile Command
Redstone Arsenal, AL 35809

Commander
HQ, Fort Huachuca
ATTN: Tech Ref Div
Fort Huachuca, AZ 85613

Commander
US Army Intelligence
Center & School
ATTN: ATSI-CO-MD
Fort Huachuca, AZ 85613

Commander
US Army Yuma Proving Ground
ATTN: Technical Library
Bldg 2105
Yuma, AZ 85364

Dr. Frank D. Eaton
Geophysical Institute
University of Alaska
Fairbanks, AK 99701

Naval Weapons Center
Code 3918
ATTN: Dr. A. Shlanta
China Lake, CA 93555

Commanding Officer
Naval Envir Prediction Rsch Facility
ATTN: Library
Monterey, CA 93940

Sylvania Elec Sys Western Div
ATTN: Technical Reports Li
PO Box 205
Mountain View, CA 94041

Geophysic Officer
PMTI Code 3251
Pacific Missile Test Center
Point Mugu, CA 93042

Commander
Naval Ocean Systems Center
(Code 4473)
ATTN: Technical Library
San Diego, CA 92152

Meteorologist in Charge
Kwajalein Missile Range
PO Box 67
APO San Francisco, CA 96552

Director
NOAA/ERL/APCI R31
RB3-Room 567
Boulder, CO 80302

Dr. B. A. Silverman D-1200
Office of Atmos Resources Management
Water and Power Resources Service
PO Box 25007 Denver Federal Center, Bldg. 67
Denver, CO 80225

Hugh W. Albers (Executive Secretary)
CAO Subcommittee on Atmos Rsch
National Science Foundation Room 510
Washington, DC 2055

Dr. Eugene W. Bierly
Director, Division of Atmos Sciences
National Science Foundation
1800 G Street, N.W.
Washington, DC 20550

Commanding Officer
Naval Research Laboratory
Code 2627
Washington, DC 20375

Defense Communications Agency
Technical Library Center
Code 222
Washington, DC 20305

Director
Naval Research Laboratory
Code 5530
Washington, DC 20375

Dr. J. M. MacCallum
Naval Research Laboratory
Code 1409
Washington, DC 20375

HOA (DAEN-RDM/Dr. de Percin)
Washington, DC 20314

The Library of Congress
ATTN: Exchange & Gift Div
Washington, DC 20540

Mil Asst for Atmos Sci Ofc of
the Undersecretary of Defense
for Rsch & Engr/E&LS - RM 3D129
The Pentagon
Washington, DC 20301

AFATL/DLODL
Technical Library
Eglin AFB, FL 32542

Naval Training Equipment Center
ATTN: Technical Information Center
Orlando, FL 32813

Technical Library
Chemical Systems Laboratory
Aberdeen Proving Ground, MD 21010

US Army Materiel Systems
Analysis Activity
ATTN: DRXSY-MP
APG, MD 21005

Commander
ERADCOM
ATTN: DRDEL-PA/ILS/-ED
2800 Powder Mill Road
Adelphi, MD 20783

Commander
ERADCOM
ATTN: DRDEL-ST-T (Dr. B. Zarwyn)
2800 Powder Mill Road
Adelphi, MD 20783
02

Commander
Harry Diamond Laboratories
ATTN: DELHD-CO
2800 Powder Mill Road
Adelphi, MD 20783

Chief
Intel Mat Dev & Spt Ofc
ATTN: DELEW-WL-I
Bldg 4554
Fort George G. Mead, MD 20755

Acquisitions Section, IRDB-D823
Library & Info Svc Div, NOAA
6009 Executive Blvd.
Rockville, MD 20752

Naval Surface Weapons Center
White Oak Library
Silver Spring, MD 20910

Air Force Geophysics Laboratory
ATTN: LDC (A. S. Carten, Jr.)
Hanscom AFB, MA 01731

Air Force Geophysics Laboratory
ATTN: LYD
Hanscom AFB, MA 01731

Meteorology Division
AFGL/LY
Hanscom AFB, MA 01731

The Environmental Research
Institute of MI
ATTN: IRIA Library
PO Box 8618
Ann Arbor, MI 48107

Mr. William A. Main
USDA Forest Service
1407 S. Harrison Road
East Lansing, MI 48823

Dr. A. D. Belmont
Research Division
PO Box 1249
Control Data Corp
Minneapolis, MN 55440

Commander
Naval Oceanography Command
Bay St. Louis, MS 39529

Commanding Officer
US Army Armament R&D Command
ATTN: DRDAR-TSS Bldg 59
Dover, NJ 07801

Commander
ERADCOM Scientific Advisor
ATTN: DRDEL-SA
Fort Monmouth, NJ 07703

Commander
ERADCOM Tech Support Activity
ATTN: DELSD-L
Fort Monmouth, NJ 07703

Commander
HQ, US Army Avionics R&D Actv
ATTN: DAVAA-0
Fort Monmouth, NJ 07703

Commander
USA Elect Warfare Lab
ATTN: DELEW-DA (File Cy)
Fort Monmouth, NJ 07703

Commander
US Army Electronics R&D Command
ATTN: DELCS-S
Fort Monmouth, NJ 07703

Commander
US Army Satellite Comm Agency
ATTN: DRCPM-SC-3
Fort Monmouth, NJ 07703

Commander/Director
US Army Combat Surv & Target
Acquisition Laboratory
ATTN: DELCS-D
Fort Monmouth, NJ 07703

Director
Night Vision & Electro-Optics Laboratory
ATTN: DELNV-L (Dr. R. Buser)
Fort Belvoir, VA 22060

Project Manager, FIREFINDER
ATTN: DRCPM-FF
Fort Monmouth, NJ 07703

PM, Firefinder/PEMBASS
ATTN: DRCPM-FER-TM
Fort Monmouth, NJ 07703

6585 TG/WE
Holloman AFB, NM 88330

AFWL/Technical Library (SUL)
Kirtland AFB, NM 87117

AFWL/WE
Kirtland, AFB, NM 87117

TRASANA
ATTN: ATAA-SL (D. Anguiano)
WSMR, NM 88002

Commander
US Army White Sands Missile Range
ATTN: STEWS-PT-AL
White Sands Missile Range, NM 88002

Rome Air Development Center
ATTN: Documents Library
TSLD (Bette Smith)
Griffiss AFB, NY 13441

Environmental Protection Agency
Meteorology Laboratory, MD 80
Rsch Triangle Park, NC 27711

US Army Research Office
ATTN: DRXRO-PP
PO Box 12211
Rsch Triangle Park, NC 27709

Commandant
US Army Field Artillery School
ATTN: ATSF-CD-MS (Mr. Farmer)
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: ATSF-CF-R
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: Morris Swett Library
Fort Sill, OK 73503

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-M
(Mr. Paul Carlson)
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: MT-DA-L
Dugway, UT 84022

US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-T
(Dr. W. A. Peterson)
Dugway, UT 84022

Inge Dirmhirn, Professor
Utah State University, UMC 48
Logan, UT 84322

Defense Technical Information Center
ATTN: DTIC-DDA-2
Cameron Station, Bldg. 5
Alexandria, VA 22314
12

Commanding Officer
US Army Foreign Sci & Tech Cen
ATTN: DRXST-IS1
220 7th Street, NE
Charlottesville, VA 22901

Naval Surface Weapons Center
Code G65
Dahlgren, VA 22448

Commander
US Army Night Vision
& Electro-Optics Lab
ATTN: DELNV-D
Fort Belvoir, VA 22060

Commander
USATRA DOC
ATTN: ATCD-FA
Fort Monroe, VA 23651

Commander
USATRA DOC
ATTN: ATCD-IR
Fort Monroe, VA 23651

Dept of the Air Force
5WW/DN
Langley AFB, VA 23665

US Army Nuclear & Cml Agency
ATTN: MONA-WE
Springfield, VA 22150

Director
US Army Signals Warfare Lab
ATTN: DELSW-OS (Dr. Burkhardt)
Vint Hill Farms Station
Warrenton, VA 22186

Commander
US Army Cold Regions Test Cen
ATTN: STECR-OP-PM
APO Seattle, WA 98733